GUGGENHEIM AERONAUTICS LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PART II

CONVERSION OF DOUGLAS DC-3 COMMERCIAL AIRPLANE FOR MILITARY PURPOSE

Addition to Thesis by
Lieut. V. Martinez,
Argentine Navy

DC-3 CONVERSION TO TROOP TRANSPORT

Study of the possibility of transformation to troop transport (as suggested by item 6 of CONCLUSIONS of the first part) became unnecessary by the time this work was under way, due to information showing that such transformation has already been made and bears the name of C-47, as illustrated by enclosed picture taken from Life magazine, August 6, 1942.

Moreover, the above mentioned photographs are informative enough for the general arrangement of the redesigned airplane.

The C-47 is more than a troop transport conversion of the DC-3, since its reinforced floor allows it to be used as a cargo airplane or troop transport alternatively.

Detailed design of seat attachments to fuselage will not be done in the present thesis, but will be left for the time when either the actual airplane or a proper mock-up is available.

It is well to observe that the scooped-out type of seat is a good choice for the seat-back chutes of parachute troops. These seats being collapsible against the sides of the airplane allow a rapid change to cargo carrier.

The tank adaptation inside the fuselage to extend the range beyond its normal 2000 miles is not necessary for the Argentine purpose.

DISCUSSION OF ITEM 6 OF

"ADDITIONAL ITEMS TO DESIGN, COMPUTE OR CHECK"

After several tentative designs of the top gun station protruding outward, the following conclusions were reached:

a. It is unnecessary to design a new frame protruding outward in order to have the station to do so.

b. It is sufficient to use the frame design as indicated in the first part of this work, then adapt a gun blister high enough to have its spherical dome out of the fuselage's top.

c. The gun ring may then be placed at any reasonable height inside the blister and the latter may or may not be faired around.

d. Gun blister not to be designed until actual plane or mock-up is available, since dimensions have to be fairly accurate. For this purpose, it is suggested to consider top gun installations of the following airplanes

	Page
Airspeed Oxford	10.14
Avro Anson	10.11
Bristol Blenheim	10.10
Handley Page Harrow	10.04
Proposed sketches	8.10 and 8.09

as sketched in Aircraft Design Sketch Book of the Lockheed Aircraft Corporation in the pages indicated above.

CONE OF FIRE STOPS

1. Limiting stop for top gun to protect vertical fin is indicated in attached drawing N where location of the three fire stations is shown.
2. Location of stops for side gun stations will require either actual plane or mock-up available.
3. No forward stop designed for top gun, since not intended for use forward below horizontal plane tangent to top skin of fuselage at fire station. All parts of airplane forward of top fire station are below mentioned horizontal plane.

MAX VELOCITY DROP

References: Diehl p. 306-307
Milliken p. 129-130
NACA T R 654

Equivalent parasite areas:

Top machine gun (with blister) $f_1 = \frac{D_1}{q} = \frac{40}{0.00256 \times (212)^2} = 0.372$

where 40 lb. has been taken as proper drag value for faried gun at 212 m.p.h. aligned fore and aft.

Two side guns: (with blisters) $f_2 = \frac{D_2}{q} = \frac{90}{0.00256 \times (212)^2} = 0.835$

where 45 lb. has been taken as proper value for each blister with gun cross-wind.

Twelve 100 kilo bombs under center panel:

$$f_3 = D_o + 12 \times 0.040 \, W_B$$

$W_b = 100$ $D_o = 100$ lb. (estimated)

$f_3' = 100 + 12 \times 0.040 \times 100 = 148$

$f_3' = \frac{f_3'}{q} = \frac{148}{0.00256 \times (212)^2} = 1.37$

Total equivalent parasite area added:

$f = f_1 + f_2 + f_3 = 2.577 \text{ ft}^2$

Approximate estimation of total equivalent parasite area for the airplane:

$f = C_{Dpe} \times S$

Where $C_{Doe} = 0.03$ is a fair value

and $S = 987$ ft.^{2} for DC-3

$\therefore$ $f = 0.03 \times 987 = 29.6$ ft.^{2}

So percentage increase in equivalent parasite area is:

$$\Delta f = \frac{2.577 \times 100}{29.6} = 8.67\%$$

Milliken p. 129 for 1% variation in f for a $\lambda_i = 15$ gives

$$\frac{\partial V_{max}}{V_{max}} = -0.32\%$$

for variation $f = 8.67\%$

Speed variation $0.32 \times 8.67 = 2.78\%$

Total speed variation for max velocity:

$$\frac{2.78 \times 212}{100} = 5.9 \text{ m.p.h.}$$

New max speed will be for the converted airplane

$V_{max} = 206$ m.p.h.

Plus or minus three per cent to take care of estimates made on items that should require experimental determination.

Note: No interference effect has been taken into account. Until more information on actual dimensions of bomb racks be available, it is hoped that the plus or minus three per cent will cover this too.

LOCKHEED 14 CONVERSION

Having found as one of the conclusions for the D-C-3 conversion that such airplane would be poorly protected against enemy fire from ahead, a similar tentative conversion will be analyzed here for the Lockheed 14 G 3 B airplane, which has more room at the nose and it is expected to be able to locate a nose gun station.

This analysis will probably cover only the location, weight and balance; since detailed transformation would require a Lockheed set of blue prints, which are not obtainable under the circumstances.

Balance (Rough)

Table I (Lockheed)

Condition 1 -- Military arrangement -- worst tail heavy

Weights added		W(lb)	Arm(in)	M(lb.in)
8	"100 kilo" bombs	1765	188.3	332,500
2	Bomb racks	442	188.3	83,300
1	Top rear gunner (equipped)	200	370.0	74,000
1	Nose gunner (equipped)	Removed for tail heavy (200 lb.)		
2	Rear-side gunners(equipped)	400	430.0	172,000
1	Add structure side guns (support only)	12	370.0	4,440
2	Add structure side guns (support only)	12	430.0	5,160
1	Add structure nose gun (support only)	15	30.0	450
	Ammunition top rear gun	150	370.0	55,500
	Ammunition rear side guns	100	430.0	43,000
	Ammunition nose gun	Removed for tail heavy (100 lb.)		
1	Top rear gun 50 cal.	50	370.0	18,500
2	Side 50 cal. guns	100	430.0	43,000
1	Nose gun	Removed for tail heavy (50 lb.)		
1	Top rear gun seat	15	370.0	5,550
	Add structure for stress top rear cutout	30	370.0	11,100
	Add structure for stress two side cutouts	50	430.0	21,500
	Add structure for stress nose gun cutout	30	30.0	900
	Totals	3,371 lbs.		870,900 lb. in.

Arms referred to fuselage nose

Items removed for tail heavy condition weigh 350 lbs. The actual maximum weight for military arrangement is:

W = 3,721 lbs.

Overload = 3,721 - 3,32.10 = 486.60 lbs.

being the useful load for this airplane only 6,475 lbs. we are beyond the 5% overload allowed in article 10 of TENTATIVE SPECIFICATIONS.

It is considered advisable to ask for a 10% allowance instead of 5% for this airplane, since higher powers are available today for same airplane.

ANALYSIS FOR CONDITION 1 (ROUGH BALANCE)

a. The worst tail heavy military arrangement gives a moment

$$M_1 = 870900 \text{ lb. in.}$$

(as shown in Table I)

b. To compare, we shall take the airplane empty and then fill the cabin and baggage compartment, giving moments as follows:

Passengers rows 1 to 7		686450 lb.in.
Stewardess		56600
Buffet supplies		45000
Baggage compartment	900 lb.	50500
Total		838550 lb.in.

Differential moment:

$$870900 - 838550 = 31350 \text{ lb.in.}$$

Military arrangement for worst tail heavy condition gives an extra 3.8% moment toward the tail.

c. Being all moments above referred to the fuselage's nose this unbalance will not be taken into account until further information, resulting from moments to the MA center, is available.

d. Note that no fuel arrangement has been resorted to.

Balance (rough)

TABLE II (Lockheed)

Commercial weights removed **(nose heavy)**

	Weight	Arm	Moment	
Stewardess	130	436.00	56,600	
Buffet supplies	100	450.00	45,000	
				101,600
Passengers				
Row 1 (2)	340	174.00	59,150	
Row 2 (2)	340	215.00	73,100	
Row 3 (2)	340	252.00	85,600	
Row 4 (2)	340	289.00	98,300	
Row 5 (2)	340	326.00	110,800	
Row 6 (2)	340	363.00	123,500	
Row 7 (2)	340	400.00	136,000	
				686,450
Furnishings				
Passengers' seats	413	288.43	119,200	
Stewardess' seat	12	436.00	5,225	
Floor coverings	50.80	295.00	15,000	
Upholstry and trim	139.80	277.42	38,750	
Curtains	6.80	300.00	2,040	
	3,232.40			180,215
				968,265

Total weight removed = 3,232.40 lbs.

Total negative (diving) moment = 968,265 lb. in.

Arms referred to fuselage's nose.

ANALYSIS FOR CONDITION 2 (ROUGH BALANCE)

a. A negative (diving) moment:

$$M_2 = 968265 \text{ lb.in.}$$

results from commercial weights removed.

b. The following fixed items of the military arrangement will furnish some positive moment:

	W	Arm	M
add structure top rear gun	30	370	11100
ditto 2 side cutouts	50	430	21500
minus ditto nose gun structure	30	- 30	- 900
two bomb racks	442	188.3	83300
TOTAL			115050

Left to be balanced 968265 - 115050 =853215 lb.in.

c. To compare, assume cabin commercial full and remove as follows:

	Moment	
passengers rows 1 to 7	686450	
stewardess plus buffet	101600	
	788050	lb.in.
d. Add 900 lbs. baggage comp.	50500	
	838550	lb.in.

Unbalance 853215 - 838550 = 14665 lb. in.

Compared with the M_2 gives 1.5% unbalance

Note that no fuel arrangement has been resorted to.

TABLE III (Lockheed)

Balance respect to MA center (Sta 181,507)

Condition 1 (a) worst tail heavy, military equipped

Weights added		W(lb)	Arm(in)	M(lb.in.)
8	"100 Kilo" bombs	1765	6.8	12,000
2	Bomb racks 20%	442	6.8	3,000
1	Top rear gunner (equipped)	200	188.5	37,650
1	Nose gunner (equipped)	Removed for tail heavy (200lb.)		
2	Rear side gunners (equipped)	400	248.5	99,400
1	Add structure top rear gun support only	12	188.5	2,260
2	Add structure side guns supports only	12	248.5	2,980
1	Add structure nose gun support only	15	-151.5	-2,270
	Ammunition top gun rear	150	188.5	28,200
	Ammunition rear side guns	100	248.5	24,850
	Ammunition nose gun	Removed for tail heavy (100 lb)		
1	Top rear gun 50 cal.	50	188.5	9,420
2	Side 50 cal. guns	100	248.5	24,850
1	Nose gun	Removed for tail heavy (50 lb)		
1	Top rear gun seat	15	188.5	2,820
	Add structure for stress top rear cutout	30	188.5	5,650
	Add structure for stress two side cutouts	50	248.5	12,420
	Add structure for stress nose gun cutout	30	-151.5	-4,540
		Total	= +	258,690

Arms referred to MA center

TABLE IV (Lockheed)

Tail heavy condition as commercial

2	pass. row 2	340	33.5	11,400
2	pass. row 3	340	70.5	24,000
2	pass. row 4	340	107.5	36,600
2	pass. row 5	340	144.5	49,200
2	pass. row 6	340	181.5	61,700
2	pass. row 7	340	218.5	74,400
	stewardess	130	254.5	33,100
	buffet supplies	100	268.5	26,850
			Total	317,250

Analysis of condition 1a -- Worst tail heavy

A. a. Table III shows a max positive moment equal to 258,690 lb. in. for the worst tail heavy military arrangement.

b. Table IV, above, shows a positive moment equal to 317,250 lb. in. for a commercial arrangement for which the airplane has to be CAA approved.

c. As both moments are now referred to the MA center, this estimation is correct and replaces entirely the former analysis of condition 1 (rough balance), its table and conclusion.

d. Conclusion: The airplane balances for the worst tail heavy military arrangement.

TABLE V (Lockheed)

Balance respect to MA center (Sta 181,507)

Condition 2(a) -- Worst nose heavy, military arrangement

Removed (-) Added (+)	Weight	Arm	Moment	
Stewardess	-130	254.5	-33,100	
Buffet supplies	-100	268.5	-26,850	
				- 59,950
Passengers				
Row 1 (2)	-340	- 7.5	+ 2,550	
Row 2 (2)	-340	33.5	-11,400	
Row 3 (2)	-340	70.5	-24,000	
Row 4 (2)	-340	107.5	-36,600	
Row 5 (2)	-340	144.5	-49,200	
Row 6 (2)	-340	181.5	-61,700	
Row 7 (2)	-340	218.5	-74,400	
				-254,750
Furnishings				
Passengers' seats	-413	106.9	-44,100	
Stewardess' seat	- 12	254.5	- 3,050	
Floor coverings	- 50	113.5	- 6,750	
Upholstery and trim	-139.8	95.9	-13,400	
Curtains	- 6.8	118.5	- 800	
				- 68,100
Nose weights added				
Nose gunner equipped	+200	-151.5	-30,300	
Ammunition for nose gun	+100	-151.5	-15,150	
Add structure for nose gun (support and reinforce)	+ 45	-151.5	- 6,820	
				- 52,270
Fixed tail weights added				
Structure for top rear gun	+ 42	+188.5	+ 7,920	
Structure for side rear guns	+ 62	+248.5	+15,400	
				+ 23,320
				-411,750 lb. in.

TABLE VI (Lockheed)

Balance respect to MA center (Sta 181,507)

Special commercial condition to compare with 2a

Removed (-) Added (+)

	Weight	Arm	Moment	
Stewardess	-130	254.5	-33,100	
Buffet supplies	-100	268.5	-26,850	
				- 59,950
Passengers				
Row 1 Added	+340	- 7.5	- 2,550	
Row 2 Removed	-340	33.5	-11,400	
Row 3 "	-340	70.5	-24,000	
Row 4 "	-340	107.5	-36,600	
Row 5 "	-340	144.5	-49,200	
Row 6 "	-340	181.5	-61,700	
Row 7 "	-340	218.5	-74,400	
				-259,850
Baggage				
Full load capacity	+900	-125.5	-113,000	
				-113,000
				-432,800 lb.in.

Analysis of condition 2a -- Worst nose heavy (Table V)

a. Worst nose heavy military arrangement produces a negative (diving) moment of 411,750 lb.in.

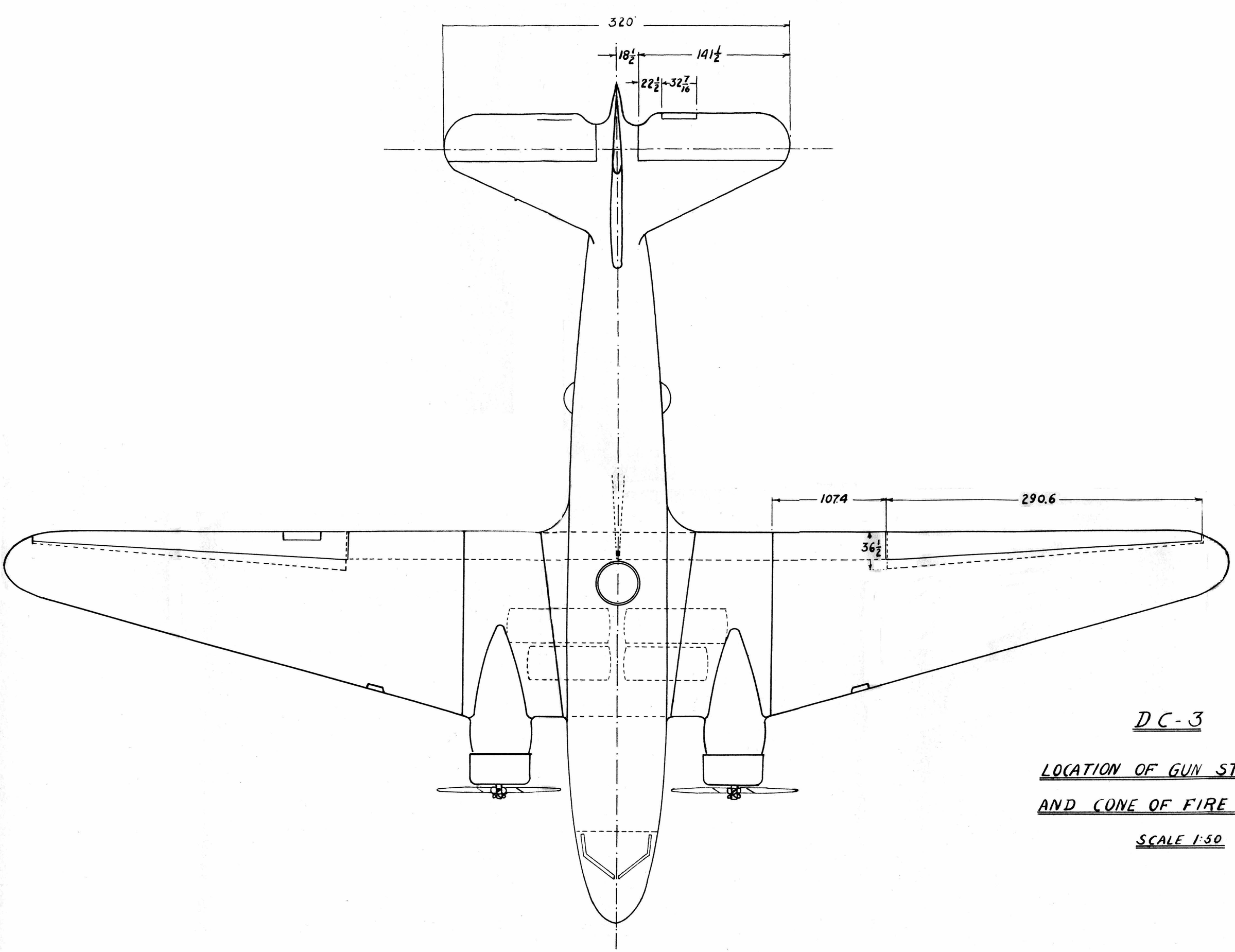
b. There exists a commercial arrangement, as shown in Table VI, producing -432,800 lb.in. diving moment, and the airplane has to be CAA approved for this condition.

c. Conclusion: The worst nose heavy military arrangement balances within correct limits.

Final balance conclusion: Airplane as converted is safely balanced for the two worst military arrangements.

NO. 2 RADIOMAN and bottom turret gunner, Private Harold Leroy Langhofer, 24, of H[illegible], K[illegible], squeezes into his turret (*above*). Inside, curled like an embryo, he can turn turret a[illegible]l and down so that it fires in any direction. When swung down, turret hatch opens into the plane.

NO. 2 AERIAL ENGINEER and waist gunner, Private Clarence Bauer, 20, [illegible]drian, Mich., pokes his .50-cal. machine gun out of side window (*below*). He mans only this gu[illegible]dio operator handles other waist gun. In flight, all crew wear headphones connecting to pilot and each other.



DC-3

LOCATION OF GUN STATIONS AND CONE OF FIRE STOPS

SCALE 1:50